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Title:

OPTICAL SWITCH ASSEMBLY AND METHOD FOR MAKING

Inventor:

Noel HEIKS
David W. SHERRER

Dickstein Shapiro Morin
& Oshinsky LLP
2101 L Street, N.W.
Washington, D.C. 20037
(202) 785-9700

OPTICAL SWITCH ASSEMBLY AND METHOD FOR MAKING

[0005] This application claims priority from provisional application serial no. 60/228,430, filed August 28, 2000, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

[0010] The present invention generally relates to optical switches, and more particularly to an assembly and a method for ensuring accurate alignment of optical fibers within an optical switch.

[0015] Conventional optical switches operate by displacing at least one of the fibers to contact the other fiber (closed position) or to release contact with the other fiber (opened position). Generally, the optical fibers connect one another at ends which are transverse to the longitudinal axis of the fibers and coplanar to one another. In the closed position, input light is transmitted from one optical fiber to the other with little or no transmission loss. In the opened position, input light is reflected from one of the fibers, leading to complete or partial transmission loss. Complete transmission loss occurs during total internal reflection, when light approaches a dielectric interface at or above a critical angle and is thereby inhibited from being transmitted to the other optical fiber. When the angle is below the critical angle, or the distance between the optical fibers is sufficiently small, some input light may cross the gap between the optical fibers and thereby frustrate the

total internal reflection. An example of such a conventional optical switch is described in U.S. patent number 5,390,266 (Heitmann et al.).

[0020] One disadvantage in conventional optical switches is obtaining an accurate fiber to fiber alignment. An accurate alignment between fibers assures low insertion loss. For example, a displacement of one fiber relative to the other, either horizontally or vertically, of more than 1 micron will likely produce unacceptable insertion loss.

SUMMARY

[0025] The invention provides an optical switch assembly that includes a fixed optical array, a movable optical array, a plurality of first optical fibers mounted on the fixed optical array and a plurality of second optical fibers mounted on the movable optical array, and a mounting apparatus. The fixed optical array is immobile relative to the mounting apparatus and the movable optical array is movable along the mounting apparatus.

[0030] The invention also provides a method for making an optical switch assembly. The method includes positioning a plurality of first optical fibers in a first support structure and a plurality of second optical fibers in a second support structure, mounting the first and second support structures on at least one mounting apparatus, and affixing one of the first and second support structures to the mounting apparatus.

[0035] The foregoing and other advantages and features of the invention will be more readily understood from the following detailed description of the invention, which is provided in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0040] FIG. 1 is a side view of an optical switch assembly constructed in accordance with an embodiment of the invention.

[0045] FIG. 2 is a cross-sectional view taken along line II-II of the optical switch assembly of FIG. 1.

[0050] FIG. 3 is a cross-sectional view of an optical switch assembly constructed in accordance with another embodiment of the invention.

[0055] FIG. 4 is a cross-sectional view of an optical switch assembly constructed in accordance with another embodiment of the invention.

[0060] FIG. 5 is a cross-sectional view of an optical switch assembly constructed in accordance with another embodiment of the invention.

[0065] FIG. 6 is a bottom view of the optical switch assembly of FIG. 5.

[0070] FIG. 7 is a side view of an optical switch assembly constructed in accordance with another embodiment of the invention.

[0075] FIG. 8 is a top view of an optical switch assembly constructed in accordance with another embodiment of the invention.

[0080] FIG. 9 is a cross-sectional view taken along line IX-IX of the optical switch assembly of FIG. 8.

[0085] FIG. 10 is a top view of an optical switch assembly constructed in accordance with another embodiment of the invention.

[0090] FIG. 11 is a flow diagram of steps taken to ensure accurate fiber to fiber alignment in an optical switch in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0095] Referring to FIGS. 1-2, in which like numerals designate like elements, an optical switch assembly 10 is shown including a base structure, such as a substrate 12, having a pair of mounting structures, shown as rails 14, a fixed optical array 20 and a movable optical array 30. The fixed optical array 20 includes a support structure, such as a chip 22, that has a face 23 and first and second surfaces 24, 26. The first surface 24 includes a plurality of first surface grooves 25, and the second surface 26 includes a plurality of second surface grooves 27. The movable optical array 30 includes a support structure, such as a chip 32, that has a face 33 and first and second surfaces 34, 36. The first surface 34 has a plurality of first surface grooves 35, and the second surface 36 has a

plurality of second surface grooves 37. The chips 22, 32 and the substrate 12 are preferably formed of silicon.

[0100] Each of the optical arrays 20, 30 is mounted on the substrate 12. Specifically, the fixed array 20 is mounted such that the rails 14 extend into the grooves 25. Preferably, an adhering material is utilized to place the rails 14 and the grooves 25 immovable relative to each other. The movable array 30 is mounted such that the rails 14 extend into the grooves 35 in such a way as to permit free movement of the array 30 along the rails 14.

[0105] Upon each of the optical arrays 20, 30 are mounted one or more optical fibers, which are preferably formed of silica. As shown, a plurality of optical fibers 28b are mounted within the grooves 37 of the chip 32, and corresponding optical fibers 28a are mounted within the grooves 27 of the chip 22. The optical fibers 28a, 28b may be adhered to the grooves 27, 37 through the use of an adhering material or mechanism (not shown). Any suitable adhering material or mechanism may be used, such as, for example, ultraviolet curable epoxy, solder, aluminum dioxide direct bonding, or solgel glass.

[0110] The optical fibers 28a, 28b have endfaces, respectfully, endfaces 29a, 29b. The optical switch assembly 10 is shown in FIG. 1 with the optical arrays 20, 30 in the opened position with the endfaces 29a, 29b being separated a distance. In such a position, as light travels down the optical fiber 28b in a direction A, the light meets the endface 29b, which acts as a dielectric interface, and is translated into reflected light which is reflected in a direction B. In the closed position, the input light passes through the endfaces 29a, 29b

and continues its transmission from the optical fiber 28a to another optical fiber. By moving the optical array 30 in a direction C, the optical switch will be placed in either an opened or a closed position. Although not shown, another fiber array may be placed vertically with respect to the chip 32 to receive reflected light B.

[0115] The rails 14 as illustrated in FIGS. 1-2 are shaped having a rectangular configuration. However, it is to be understood that any suitably shaped rail may be utilized. For example, a substrate 112 is shown in FIG. 3 which differs from the substrate 12 in that it includes a pair of rails 114 which are semi-circular in configuration.

[0120] It should be further understood that the chip 32 may slide on mounting structures which are not integral with the base structure. As shown on FIG. 4, the chip 32 may be slidably mounted on a substrate 212. The substrate 212 differs from the substrate 12 and 112 in that it lacks integral rails, such as the rails 14 or 114, and instead has grooves 213. A fiber 214 is positioned in each groove 213, and the fibers 214 are held in place with an adhesive 215. Obviously, to prevent movement of the chip 22 (FIGS. 1-2), the chip 22 may be adhered to the fibers 214 or otherwise rendered immobile relative thereto.

[0125] Although FIGS. 1-4 illustrate optical switch assemblies having optical fibers mounted on an upper surface of a chip, i.e., the surface furthest from the substrate, it should be understood that the invention is not so limited. With specific reference to FIGS. 5-6, there is illustrated an optical switch assembly 50 having a pair of chips 42, 43 and a

substrate 52. The chips 42, 43 include a first set of grooves 47 and a second set of grooves 45. The substrate 52 includes a pair of rails 54 and an opening 56. The chips 42, 43 are mounted on the substrate 52 such that the rails 54 are positioned within the second set of grooves 45. One of the chips 42, 43 is movable relative to the other chip and the substrate, while one of the chips 42, 43 is affixed to the substrate 52.

[0130] The optical fibers 28a, 28b are mounted within said first set of grooves 47 and are affixed therein through the use of an affixing mechanism, such as by laser welding or with an adhering material such as, for example, an epoxy. The opening 56 is sufficiently large to extend across all of the optical fibers mounted within the grooves 47. As shown, the optical fiber arrays are in the opened position in that the endfaces 29a, 29b are separated a distance. In such a position, as light travels down one of the optical fibers, for example optical fiber 28b, the light meets the endface 29b, which acts as a dielectric interface, and is translated into reflected light which is reflected through the opening 56.

[0135] It further should be understood that elements other than fibers may be utilized for mounting the support structures. As shown in FIG. 7, an optical switch assembly 310 is illustrated including the substrate 212, the fixed optical array 20 and the movable optical array 30. The optical arrays 20, 30 are each mounted on, respectively, spheres 314', 314. The spheres 314 beneath the movable optical array 30 seat within the grooves 213 of the substrate 212. The spheres 314' beneath the fixed optical array 20 are affixed to the grooves 213 with the adhesive 215. The movable optical array 30 moves with the spheres 314 along the grooves 213. Since the spheres 314' are fixed relative to the grooves 213,

their immobility is translated to the fixed optical array 20. The spheres 314 are made of a material suitable for translating motion to the movable optical array, such as, for example, silica or alumina, and the spheres 314' may be made from the same or different materials.

[0140] FIGS. 8-9 illustrate another optical switch assembly 410, which includes a fixed optical array 420, a movable optical array 430, and a pair of fiber rails 418. As shown in FIG. 9, the fixed optical array 420 includes an upper fixed chip 412 and a lower fixed chip 422. The upper fixed chip 412 includes a surface 414 which mates with an opposite surface 424 on the lower fixed chip 422. Each of the chips 412, 422 includes grooves 413, 423 in, respectively, the surfaces 414, 424. The grooves 413 and 423 mate with each other, providing a space through which the optical fibers 28a extend. Each of the chips 412, 422 further include a cut-in portion 419 extending from an outer surface to, respectively, surfaces 414 and 424. The cut-in portions 419 mate to create a notch. Fiber rails 418 are positioned in the notches, and the upper and lower fixed arrays 412, 422 are adhered to the notches with an adhesive 415.

[0145] The movable optical array 430 includes an upper movable chip 432 and a lower movable chip 442. The upper movable chip 432 has a surface 434 in which are located grooves 413. The lower movable chip 442 has a surface 444 which includes grooves 423. The surfaces 434 and 444 mate up such that the grooves 413 and 423 create a space through which the optical fibers 28b extend. Each of the chips 432, 442 include cut-in

portions 419 which mate to create a notch which extends from an outer surface to, respectively, the surfaces 434 and 444.

[0150] The optical fibers 28a may be adhered to the chips 412, 422 by mounting the fibers 28a in an adhesive material within the grooves 413, 423. Likewise, the optical fibers 28b may be adhered to the chips 432, 442 by adhering the fibers 28b to the grooves 413, 423.

[0155] FIG. 10 illustrates yet another embodiment of the invention. An optical switch assembly 510 is shown including a substrate 511, a fixed optical array 520, and a movable optical array 530. The substrate 511 includes a plurality of grooves 513 extending in a direction parallel to a direction D. The substrate 511 also includes a plurality of grooves 533 extending in a direction parallel to a direction E. In each groove 513 is positioned a fiber rail 518, while in each groove 533 are positioned a plurality of spheres 534. The fiber rails 518 may be adhered to the grooves 513, but the spheres 534 remain mobile within the grooves 533.

[0160] The fixed optical array 520 includes a chip 522 through which extend openings (not shown). The optical fibers 28a are affixed to the chips 512 within the openings. The movable optical array 530 has a chip 532. Openings (not shown) extend through the chip 532 into which the optical fibers 28b are affixed.

[0165] In the assembly of the optical switch assembly 510, the chip 522 is mounted on the fiber rails 518 and the chip 532 is mounted on the spheres 534. The chips 522 and

532 are aligned such that the optical fiber ends 29a and 29b are accurately aligned. Specifically, the chip 522 is moved along the direction D and chip 532 is moved along the direction E. The chip 522 is then affixed to the fiber rails 518 or otherwise rendered immobile. The chip 532 remains movable on the spheres 534. As assembled, the chip 532 may be moved into contact with the chip 522 or out of contact such that a gap 540 exists between the chips 522, 532.

[0170] Next, with specific reference to FIG. 11, will be described a method for making an optical switch assembly. At step 600, a plurality of optical fibers are positioned within or on support structures, such as chips. The optical fibers may be affixed to grooves in or on the support structures. The support structures may include upper and lower portions with mating grooves.

[0175] At step 605, the support structures are mounted on a plurality of mounting structures. One of the support structures is affixed to, or otherwise render immobile relative to, the mounting structures. The mounting structures may take the form of rails integral with a base structure, such as a substrate. Instead, the mounting structures may be fiber rails, spheres, a combination of all of the above, or some other similar mounting structure.

[0180] Some of the grooves may be formed in a direction transverse to the direction of movement between the chips. In such an arrangement, the support structures may be

aligned to each other, in step 607, by moving one of the support structures transverse to the other support structure to obtain an alignment of the optical fibers.

[0185] At step 610, one of the support structures is adhered to the mounting structures. In this way, one of the support structures can move in and out of contact with the other support structure, thereby closing and opening the optical switch.

[0190] While the invention has been described in detail in connection with the preferred embodiments known at the time, it should be readily understood that the invention is not limited to such disclosed embodiments. Rather, the invention can be modified to incorporate any number of variations, alterations, substitutions or equivalent arrangements not heretofore described, but which are commensurate with the spirit and scope of the invention. For example, although the optical switches have been shown and described with optical fibers having slanted endfaces and with chips having slanted faces, it should be noted that the invention is not so limited. The endfaces and the faces may be parallel to one another. Accordingly, the invention is not to be seen as limited by the foregoing description, but is only limited by the scope of the appended claims.